lating the flow. The square surface immersed of each element is about six square inches, and the delivery of fluid from two to four quarts per hour, when a very constant and steady light is given. When not in use the elements are lifted out of the cells and the flow of the fluid stopped. The fluid requires renewing as soon as all warmth of colour by transmitted light disappears, but it will produce a steady light until every bit of bichromate is decomposed; by simply increasing the flow as the fluid becomes weaker it will do a great many hours' work before it requires renewing.

Suggestions for Improvements in the Construction of Large Transit Circles. By A. A. Common.

The ordinary well-known form of Transit instrument, considered in regard to the purpose for which it is used, may be taken as the best designed astronomical instrument we have, fulfilling as it does, when of moderate dimensions, nearly all the required conditions. Its chief defect, inherent in the construction usually adopted, is that of flexure of the tube, and in a less degree of the axis itself. If this flexure of the tube is equal on both sides the result is only a slight movement of the optical axis parallel to itself, but if it is unequal then a change of direction necessarily follows. In either case the accuracy of the observation is not affected.

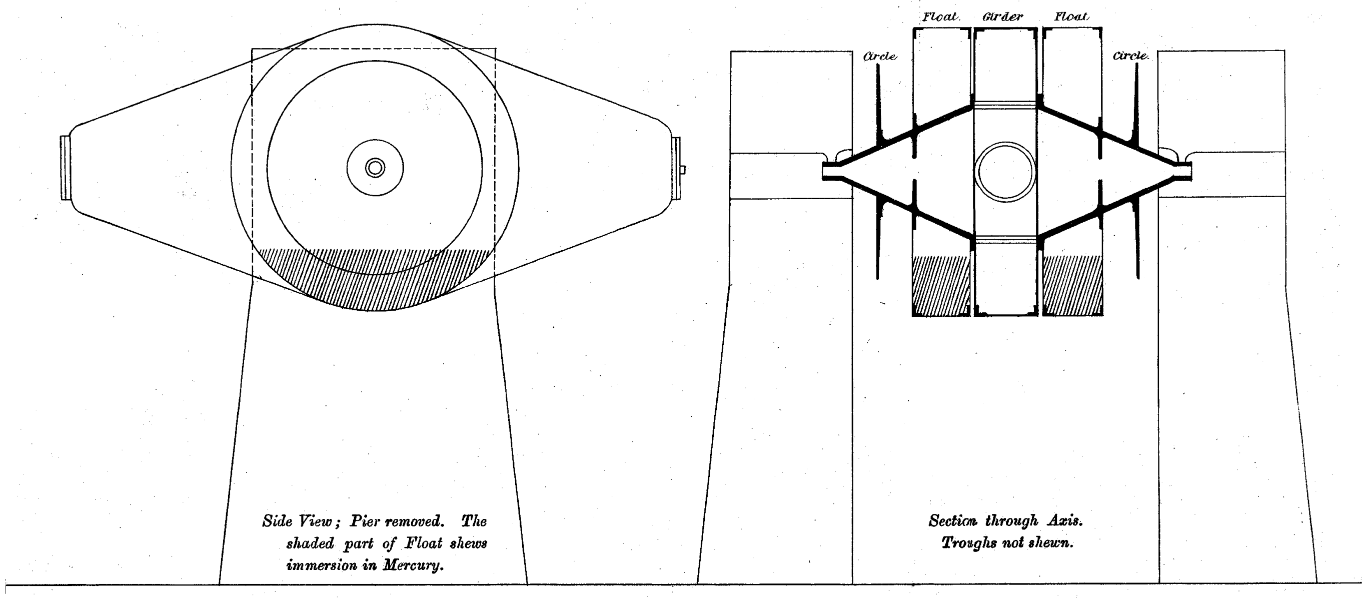
Most probably such permitted flexure would result in some change of direction of the optical axis in a plane not at right angles to the axis; but, at the worst, this resulting error is all that the Transit instrument suffers from.

When, however, this instrument, good as it may be for its own purpose, is made into a Transit Circle by placing on the axis a divided circle for the purpose of determining the direction of the optical axis in a vertical plane, without in any way altering the construction to get rid of the defect spoken of, that would here become of great importance, it cannot be said that all has been done to make it as perfect or as suitable for its purpose as possible, especially as the delicacy and refinement of observation require that the means of the astronomer should be as mechanically perfect as they can be made, so as to reduce to the lowest amount those errors that must always exist in an astronomical instrument.

Believing, as I do, that the Transit Circle, as at present made, is capable of great improvement, I wish to lay before the Society some remarks on the construction usually followed, and to offer some suggestions for consideration.

If we examine the construction of this instrument we find that, generally speaking, it is only an enlargement of the

Sketch Elevation and Section of Transit Circle, ten inches aperture, ten feet focal length.



A. A. Common.

Spottiswoode & Co. Lith. London.

ordinary Transit instrument, with the addition of a divided circle and means to read it, and that there is not any real change of plan or evidence of any attempt to meet the altered conditions of the case. Rigidity is expected from increase of metal; but, as I shall show presently, this increase is, in most cases, not so well disposed as in the model. The usual construction is something like this. There is a hollow metal cube, from two sides of which spring the cones, terminating in the pivots; this forms what may be termed the axis; to the other two opposite sides of the cube are attached, by flanges, the tubes carrying the optical points of the instrument. The remaining sides of the cube are perforated for the use of the collimators. The connection of the tubes to the cube by flanges and bolts is general, and raises the question as to the effect of bolts if screwed up unequally.

Now, if we take a section of such an axis, we find that the metal does not, at the angles formed by the cube, cover the lines of compression or tension, as the case may be, but is outside these lines—to my mind as fatal a disposition as can be imagined for such a case. If we place such an instrument with the tube horizontal what do we find takes place as the result of gravity? The hole in the upper face of the cube becomes elliptical with the major axis in the direction of the tube, for the tension of the upper sides of the tube tend to pull it so, assisted by the compression of the upper parts of the cones at right angles to this direction, the reverse action going on below; and, further, the elbows formed by the corners of the cube and the junction of the flanges with the tubes alter their angle under the stress, and the consequence is flexure, principally in the plane at right angles to the length of axis, but not either equal or confined to this plane, and necessarily of a very uncertain character, and in large heavy instruments of considerable amount. The flexure that would, in a small instrument, be lost sight of, not only from its small amount, but from the want of power in such an instrument to detect it, becomes, in a large instrument, greater in proportion to the size, and more evident in proportion to the increased power.

The connection of the divided circle (and here I would like to say that in my opinion the making of circles like wheels, that is with spokes and a rim, is wrong altogether) by which the zenith distance of the optical axis is determined is not of such a nature as affords the best results, nor can it be where the flexure of the tube is admitted, and the rigidity of the circle is presumed. Properly, there should not be any more possibility of change in one more than in the other.

The counterpoise friction wheels are usually applied near the pivots, and not, as they certainly should be, as near as possible to the centre of gravity of each half of the axis; and are all of a mechanical character, that is, wheels pressed up by weights and springs.

The pivots invariably work in Ys, either with flat faces or concave for a certain amount to fit the pivots, and oil is used between the surfaces.

In making an observation, as far as I know, the determination in declination is made by bringing the fiducial wire as near the star as possible, and determining the exact position of this fiducial wire, representing the optical axis of the telescope, by reading many microscopes, and then measuring the distance of the star from this fiducial wire by the eyepiece microscope.

There are other matters, more of detail but not less important, well worth remark, but as they are not affected by the alterations I go to propose, they need not now be touched upon.

The symmetrical form of the Transit instrument has so many advantages over any modification of the mural circle form (and there are many that suggest themselves on thinking over this subject), particularly in the power of reversal, that it should certainly be retained. Keeping as near as may be to it, I would suggest the following alterations from the plan already mentioned. (Without going too minutely into details that could only be properly dealt with by working drawings, I have endeavoured to show these at a glance in the accompanying sketches, giving farther on some figures to show size and weight.)

The main axis should be, as in the Transit instrument, of two cones, but these I would connect base to base by an overlapping ring-joint. This joint would be cut in four places to allow for the light from telescope and collimators to pass. To this axis, in place of the usual tube, I would attach two thin discs of metal, about one-tenth less in diameter than the focal length of object-glass, and at a distance apart a little more than its aperture. In the case of the focal length exceeding a moderate amount—say six or seven feet—I would use, in place of the discs, sheets shaped somewhat in the manner shown in the sketches.

These discs or sheets are to be connected by an outside band and radial plates, and to be securely fastened to the axis already named by flanges in a vertical plane.

These discs, bands, and radial plates form practically a box-girder, the depth of which in the smaller size is equal to its length, and in the larger sizes is some fraction not less than one-half.

For the purpose of supporting these discs or sheets and the axis, in place of the usual mechanical counterpoise, I would have two short hollow iron cylinders immersed in their lower part in troughs of mercury to such an amount as to give the requisite lifting power, which in this construction would be slightly greater than the whole moving mass. These cylinders would be rigidly connected to the axis and the discs or sheets, and they would be placed so as to be as near as possible to the centre of gravity of each half, to reduce all strain on the central parts as much as possible. These floating counterpoises, while not so neat-looking as the mechanical ones,

have so many advantages in their freedom from vibration, their delicacy and constancy, and above all their perfection as reducers of friction, that they are quite worth the sacrifice to appearance their use demands.

The troughs for the floats to work in would be supported from below by suitable means to allow for the lowering and raising, running out, reversal, and return of the instrument.

The divided circles may be, in the case of a moderate-sized instrument, the discs themselves, or they may be, as is usual and more convenient, fastened to the axis near the pivots. In any case the circles should have a lenticular section, or be like a plate dished out a little, and not any kind of wheel with spokes and rim.

The pivots and their supports, determining as they do the absolute position of the instrument, are of the first importance. In place of the usual Ys, I would suggest that plane surfaces be used, one horizontal and one vertical, for each pivot bearing; these planes, of some hard stone, such as black carbonate, embedded in metal blocks, and brought to a true plane surface, the pivots being kept up to contact with the horizontal plane, and not, as is usual, brought down upon it; the contact of the pivot with the vertical plane being by any suitable means, as, for instance, a slight spring or a small pressure-wheel, exerting sufficient force to overcome any tendency of the pivot to roll instead of slide on the plane when the instrument is turned. In such a case the whole of the base parts supporting the troughs would have to be counterpoised by gravity, so as to have the requisite pressure to ensure contact between pivot and plane. It will be seen that in this arrangement the duty of the pivots is only to fix the plane of rotation of the instrument, and that they can never be subject to the whole weight of the moving part, but only to the amount of pressure spoken of, that is, sufficient to ensure contact; they are in this way relieved from the possibility of undue strain, the whole weight being always borne by the floats even in the reversal. The finishing of the pivots would be done after the instrument is permanently set up.

In the ordinary form the pivots have not only to do this duty spoken of, but they have to support more or less of the whole weight, assisted by the counterpoises, but always with the probability that at some time this whole weight may be brought on them, while in lifting or reversal, the pressure is generally applied at some fresh part of axis, so bringing new strains to work. It is doubtful if such an instrument would not be permanently deformed if once left to support itself on the pivots.

The fixing of the object-glass in its cell, and the preservation of the optical axis, that is, the line joining the optical centre of object-glass and fiducial lines in eye end, from change due to alteration of temperature, would seem to be best met by engraving these lines on a piece of glass similar in size to the

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object-glass, and held, as regards its power of expansion or contraction, or the effect of this on the holder, in the same way as the object-glass. Such lines ruled on glass would be in every respect better than spider web, as not having any flexure, whilst being much finer. The use of graphite instead of oil as a lubricant would seem to have advantages in all cases, but more particularly where there is some little surface of contact, as when the Ys are made concave to suit the pivots, and would be well worth trial in existing instruments.

The use of an ordinary level would be impossible owing to the great size of the central parts between the pivots, but much might be done to get over this difficulty by using a column of mercury under each pivot, connecting the two columns below; in fact, using a U-shaped tube of a suitable width, filled with mercury, and provided with some means of causing the mercury to rise at will so as to show convex above the tops of the tubes. On placing this level so that each tube comes within about one-tenth of an inch of the underside of pivot, and applying pressure, the rise of the mercury could be watched, and the level of the two pivots got fairly well. If such a level had at the lower part of the U an enlargement in which could be placed a vertical septum of some flexible but not elastic material, that would serve as an insulator to keep the two columns electrically separate without affecting them otherwise, the contact of each column could be determined in a very exact way by a very weak battery and a fine galvanometer placed in circuit with the pivot and column of mercury, the contacts taking place at each pivot and showing on the galvanometers at the same instant if the pivots are level, when the mercury is slowly forced up. Such a level could be used with the ordinary form of Y, and in either case could be a permanent fitting. The pivots would have to be free from oil, of course, to ensure electrical contact, but the use of graphite would be favourable to this plan.

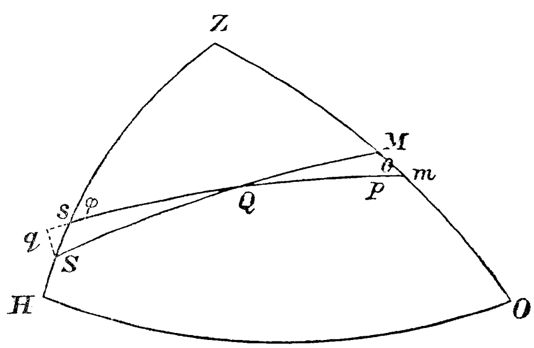
Taking the sketches given to roughly represent the moving parts of a Transit Circle of ten inches aperture, and ten feet focal length, with an axis six feet long, with a box-girder in place of discs to carry the optical parts, and provided with two circles of solid steel about three feet six inches in diameter, and allowing one hundred pounds for object-glass and eye-end fittings, we have the following approximate weights of the moving part, all in steel:—

	lbs.
The axis of cast steel 30″ diameter in two lengths with flanges	1100
The central part of steel one-fifth inch thick, including all angles, partitions, and fittings	1050
Two cylinders 56″ diameter, one-eighth metal, including all angles, etc.	700
Two circles, 42 diameter	350
Clamping gear	150
	3350

This is not an excessive weight for such a large instrument, and it is rather a question whether it might not be increased considerably. The displacement of about five cubic feet of mercury would equal it, and the cylinders of a length of one foot would give this amount of displacement with a margin. There are no mechanical difficulties in such a construction, though there are points that would require careful consideration. It allows of all the corrections and adjustments that the present instrument allows, and in the case of a small instrument where discs are used in place of what I have termed the box-girder; if required, more than one telescope, that is O. G. and eye-piece, could be used; and even a double telescope, at right angles to the principal telescope, that is, one where the O. G. of one is in front of the eye-piece of the other, and the lines of reference can be engraved on the object-glass of each; or one at some required angle from the first, for differential observations. The friction being so reduced the setting of the instrument actually on the star to be observed could be easily effected with proper clamping and moving arrangements.

A Method for Clearing a Lunar Distance. By John Merrifield.

Let Z be the zenith, HO the horizon, m and s the apparent places of Moon and other object, M and S their true places;



then $m\,s$ is apparent distance, M S the true. With pole Q describe small circles S q and M p, then

$$qp = \text{MS, the true distance.}$$

Now if

d' be the apparent distance,

d „ true „

C „ correction for ☽'s altitude

c „ „ ⊙ „

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